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Interaction of the infestation of the *Diatraea impersonatella*, varieties, and different ages of sugarcane and their agroindustrial characteristics

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ABSTRACT

Diatraea impersonatella (Walker, 1863) (Lepidoptera: Crambidae) is a key pest of sugarcane in Northeastern Brazil, yet information on its relationship with plant age and varietal traits remains scarce. This study evaluated the interaction among *D. impersonatella* infestation, sugarcane varieties (RB 92-579, RB 04-1443, and RB 86-7515), and plant age (45, 70, 130, and 200 days after planting) on agroindustrial characteristics. The experiment was conducted under field conditions in six municipalities of Paraíba State, with 144 plots selected for uniform soil and planting conditions. Infestation levels were assessed through visual diagnosis of bored stalks, while agroindustrial analyses (BRIX, POL, PURITY, FIBER, ATR, and PBU) followed standardized methodologies. Data were analyzed using generalized linear mixed models, principal component analysis, and non-parametric bootstrap. All tested varieties were infested, with RB 92-579 showing the highest susceptibility, especially as plant age increased, and exhibiting elevated Brix, purity, and POL levels. Conversely, RB 86-7515 showed a decreasing trend in infestation with plant age, lower Brix, higher PBU and fiber content, and POL, purity, and fiber values similar to RB 04-1443 but lower than RB 92-579. This study concludes that RB 92-579 is the most susceptible to *D. impersonatella*, with infestation clearly related to plant age and varietal traits. These findings provide reliable field-based insights for improving integrated pest management strategies in Northeastern Brazil's sugarcane cultivation.

Introduction

Lepidoborers are considered the main pests of sugarcane crops (Bhatti et al., 2008; Francischini et al., 2017), emphasizing species of the *Diatraea* complex (Mejía et al., 2020). Damage is caused in the larval stage, when, in search of food and shelter, the organisms penetrate the sugarcane stalks, piercing them and forming galleries (Rossato Junior et al., 2013). This process results in a decrease in the quality of the juice and plant biomass, in addition to allowing the entry of pathogens into the plant (Cruz-Tobón et al., 2023).

In Brazil, two species stand out as pests in sugarcane crops: *Diatraea saccharalis* (Fabricius, 1794) and *Diatraea impersonatella* (Walker, 1863), the latter previously identified as *Diatraea flavipennella* (Pinto, 2016), the latter being reported in all states of the Brazilian Northeast (Francischini et al., 2017). *D. impersonatella* attacks through the initial perforation of the stalks, followed by the formation of galleries, with the larvae remaining inside the plant throughout its cycle. This process can result in the death of the apical meristem, the growth of aerial roots, and the formation of lateral shoots (Rossato Junior et al., 2013). The biology and damage caused by these pests are similar to those of other lepidopteran pests that attack sugarcane (Dinardo-Miranda et al., 2013); therefore, effective control strategies are necessary.

Effective monitoring and control strategies are essential to minimize the losses caused by *Diatraea* spp. If not implemented properly, production costs will increase substantially (Gil, 2012), compromising productivity. However, chemical control is compromised due to the endophagous feeding habit and the simultaneous occurrence of immature and adult stages of the pest in the field (Freitas et al., 2007; Francischini et al., 2017).

Borer infestation is influenced by several variables, with the phenological stage of the plants being a crucial factor in the level of attack. Young plants tend to be more vulnerable to damage caused by the borer (Mendonça et al., 1996), while older plants have a higher sucrose content (Roberto et al., 2015), which serves as a food source throughout the pest's cycle. It is important to note that each sugarcane variety has defense mechanisms against herbivory and may resist certain pests, influencing the level of infestation observed.

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Understanding *D. impersonatella* infestation according to the variety and age of the sugarcane plant is of fundamental importance for implementing proactive management measures and, consequently, making more effective decisions. This will allow choosing the right time to carry out control and the best genetic material to be used in combination with other control tactics in integrated pest management, minimizing the losses caused by the insect pest. In addition, it is pertinent to relate the degree of infestation to the agroindustrial characteristics.

In this context, the present study aimed to compare the susceptibility to infestation by the borer *D. impersonatella* among the varieties RB 92-579, RB 04-1443, and RB 86-7515. Furthermore, to obtain the correlation of infestation with the varieties at 45, 70, 130 and 200 days after planting sugarcane and agro-industrial characteristics, such as soluble solids content of the juice (BRIX), FIBER content, total recoverable sugar (ATR), wet cake weight (PBU), total apparent sucrose of sugarcane (POL) and PURITY.

Material and methods

The study was carried out in Paraíba, Santa Rita, Mamanguape, Rio Tinto, Jacaraú, and Mataraca (Fig. 1), from August 2022 to May 2024. The agro-industrial analyses were carried out in the Sucrose laboratory of the Paraíba Sugarcane Planters Association (ASPLAN), in the municipality of João Pessoa-PB.

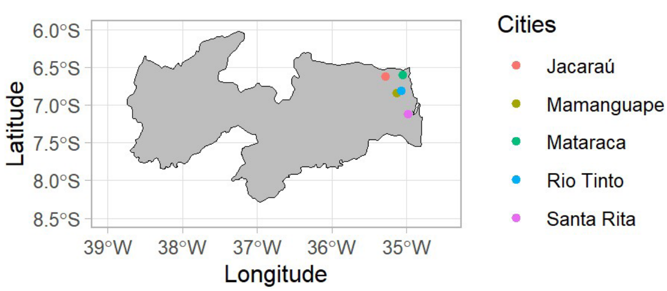

Figure 1 The study was carried out in Paraíba, Santa Rita, Mamanguape, Rio Tinto, Jacaraú, and Mataraca.

The experiment included three sugarcane varieties commonly cultivated in Northeastern Brazil: RB 92-579, RB 04-1443, and RB 86-7515, all developed by the Inter-University Network for the Development of the Sugar-Energy Sector (RIDESA). RB 92-579 is classified as early-maturing, showing high sucrose content and low fiber, suitable for short production cycles but more susceptible to borer attack. RB 04-1443 is mid-maturing, with intermediate fiber and sugar levels and moderate resistance to pests and diseases. RB 86-7515 is late-maturing, with higher fiber content and good adaptability to different environments, which increases structural resistance and reduces *D. impersonatella* infestation.

One hundred forty-four sugarcane plots were evaluated, distributed between the ages of 45, 70, 130, and 200 days after planting (DAP), planted with the varieties. Each plot had an average area of 5,000 m^2. The 144 plots were zoned to ensure representativeness across the study region, with 48 plots assigned to each sugarcane variety and distributed among the five municipalities evaluated. This distribution was designed to encompass the climatic diversity of the state and its local variations. No pest management measures were adopted in the experimental areas, allowing the natural evaluation of the infestation. The plots were randomly selected, precisely because they did not receive pest control interventions, which allowed the assessment of the natural infestation dynamics of *D. impersonatella* under field conditions.

Fertilization management in the evaluated areas followed the recommendations established by the Instituto Agronômico de Pernambuco (IPA, 2008) for sugarcane, adjusted according to the results of soil analyses conducted in each production site. The fertilization program was implemented following the local agronomic practices commonly adopted by sugar and ethanol industries in the region. All cultivation areas were managed under rainfed conditions, without supplemental irrigation. The rainfall recorded during the study period totaled 1,905.4 mm in 2022, 1,361.0 mm in 2023, and 1,323.0 mm in 2024, values representative of the climatic variability observed in the sugarcane-producing regions of the state.

To evaluate the incidence of *D. impersonatella*, four random points were selected in each plot. The plants were analyzed in one linear meter in two parallel rows at each point, totaling two meters per point. The evaluations at 45 days in the plants were carried out when there were symptoms of death of the apical meristem, known as "dead heart" (Fig. 2a). Plants with this characteristic were cut

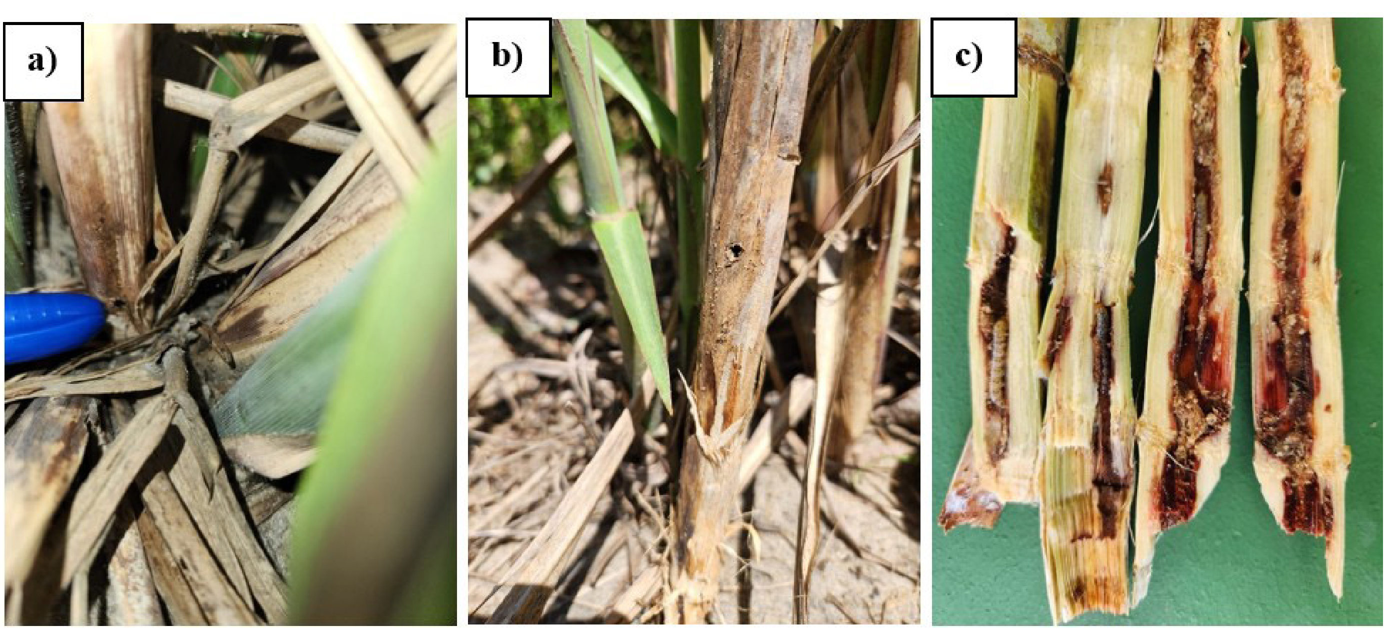

Figure 2 Visual symptoms of dead heart in the field (a); stripped stalk and visualization of pest entry and exit holes (b); opened stalks and verification of pest presence (c).

5 cm below ground level for detailed inspection. canes with formed internodes were deshucked in situ, allowing for the visual inspection of entry or exit holes made by the pest at the predetermined sampling point checking for the presence of entry or exit holes and biological forms of the pest (larvae, pupae, or adults). For plants aged 70, 130, and 200 days, the stalk was stripped entirely, followed by checking for the presence of holes (Fig. 2b). If holes were identified, the stalks were opened longitudinally to confirm the presence of the pest in its different biological stages (Fig. 2c).

The Final Infestation Intensity Index (IIIF) was determined according to the methodology cited by Simões Neto and Garcia (2016). Based on the examination of the collected samples, the IIIF was calculated as the percentage of infested stalks relative to the total number of stalks evaluated, representing the final intensity of pest attack in the area. Areas with IIIF values equal to or greater than 1% were considered infested, indicating the threshold above which yield and quality losses become significant.

In parallel with the agricultural analyses, the varieties were subjected to industrial analyses to determine the BRIX, PBU, PURITY, FIBER, POL and ATR levels. The evaluations were conducted 24 hours after harvest, considering plants with 330 days after planting (DAP), characterized as plant cane, first leaf (first production cycle). Table 1 presents the quality indicators and their recommended values for sugarcane cultivation.

The laboratory analyses were conducted following the standardized procedures adopted by the sugarcane industry for determining BRIX, POL, FIBER, PURITY, POL and ATR, as described in technical bulletins CONSECANA-SP (2015) and by Ripoli and Ripoli (2004). BRIX was determined using an automatic refractometer; POL and PURITY were obtained through clarified juice polarization; FIBER was measured as dry, water-insoluble material after filtration; ATR was calculated from sucrose concentration and juice purity; and PBU corresponded to the mass of pressed bagasse, reflecting juice extraction efficiency.

For data analysis, it was necessary to diagnose the best-fit model. It was observed that the explanatory variables conditioned the detection of overdispersion of the dependent variable, that is, plant age. The detection of overdispersion was given through the adoption of the overdisp function (Cameron and Trivedi, 2020) of R (R Core Team, 2023), which provides a fast and safe solution for the detection of overdispersion in count data (R Core Team, 2023). Through this analysis, the following diagnosis was found: Lamba's t-test score value = -3.29, and with a probability less than 5% (P = 0.0460), leading to the choice of the quasi-Poisson model.

The results were plotted using the ggplot function of the ggplot2 package, using the geom_smooth layer, the glm method, quasi-Poisson family, with a polynomial formula of degree 1, and the fullrange option = TRUE. The influence of sugarcane age on the number of bored stalks was studied by deviance analysis, and the comparison was subsequently conducted through contrasts in the quasi-Poisson generalized linear model with log link function, using the glht function of the multcomp package.

The univariate data from the industrial analyses were analyzed with a bootstrap using the dbc function, ccboot argument of the Exp.Des.pt package of R (R Core Team, 2023). The data were also subjected to multivariate principal component analysis, for which the components were calculated based on the correlation matrix. The data were standardized using the scale function, and the eigenvalues and eigenvectors were estimated using the prcomp function of the R base.

Results

It was observed that the attack of *D. impersonatella* is influenced by the variety and age of the sugarcane plant. The deviance analysis observed a significant interaction between the age and variety factors for the amount of bored stalks (F = 2.54; df **= 3**; P = 0.0230). A lower number of bored stalks was observed in plants aged 45 days, differing from those aged 70, 130, and 200. The variety RB 92-579 showed greater susceptibility when compared to the others. In addition, it was observed that the varieties RB 92-579 and RB 04-1443 showed a tendency for an increase in the number of bored stalks over time, indicating greater susceptibility to the attack. In contrast, the RB 86-7515 variety suffered more severe attacks in the early stages of the crop, but with a tendency for attacks to reduce as the plant ages (Fig. 3).

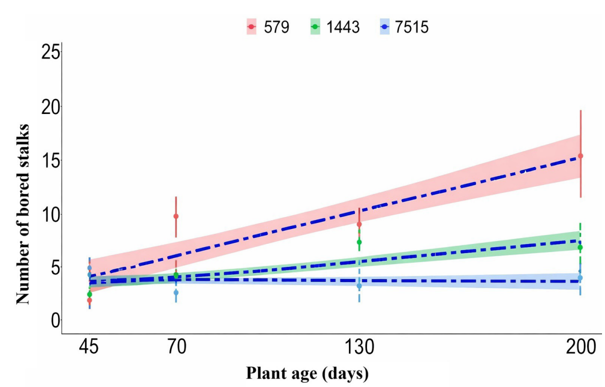

Figure 3 Incidence of stalks bored by *Diatraea impersonatella* according to the age and variety of sugarcane plants.

Table 1
Multiple correlation coefficients (r) obtained between the variables indicate the sugar concentration in sugarcane **(BRIX)**, wet cake weight **(PBU)**, total apparent sucrose in sugarcane **(POL)**, proportion of sucrose in relation to the total soluble solids in sugarcane juice **(PURITY)**, water insoluble dry material **(FIBER)** and total recoverable sugar **(ATR)**.

	BRIX	PBU	POL	PURITY	FIBER	ATR
BRIX		r= -0.500	r= 0.945	r= 0.473	r= -0.507	r= 0.888
	-	p=0.0579	p=0.0000	p=0.0752	p=0.0537	p=0.0000
PBU			r=-0.378	r=0.0321	r=0.995	r=-0.427
	-	-	p=0.1646	p=0.9096	p=0.0000	p=0.1126
POL				r=0.735	r=-0.394	r=0.933
	-	-	-	p=0.0018	p=0.1466	p=0.0000
PURITY					r=0.00353	r=0.676
	-	-	-	-	p=0.9900	p=0.0057
FIBER						r=-0.451
	-	-	-	-	-	p=0.0914
ATR						
	-	-	-	-	-	-

Table 2
Univariate bootstrap analysis between the variables: indicate the sugar concentration in sugarcane **(BRIX),** wet cake weight **(PBU)**, total apparent sucrose in sugarcane **(POL)**, proportion of sucrose in relation to the total soluble solids in sugarcane juice **(PURITY)**, water insoluble dry material **(FIBER)** and total recoverable sugar **(ATR).**

Variety	BRIX	PBU	POL	PURITY	FIBER	ATR
RB 92-579	20.10a	133.72b	18.1a	90.06a	11.96b	146.36a
RB 04-1443	19.40a	132.94b	16.72b	86.18b	11.82b	137.70a
RB 86-7515	18.14b	146.16a	15.79b	87.04b	13.81a	134.08a
F	6.8732	5.145	7.743	5.1942	5.3398	2.9506
P	0.010252	0.024346	0.006925	0.023712	0.021942	0.090739

Averages followed by the same letter in the columns do not differ from each other by the Bootstrap test

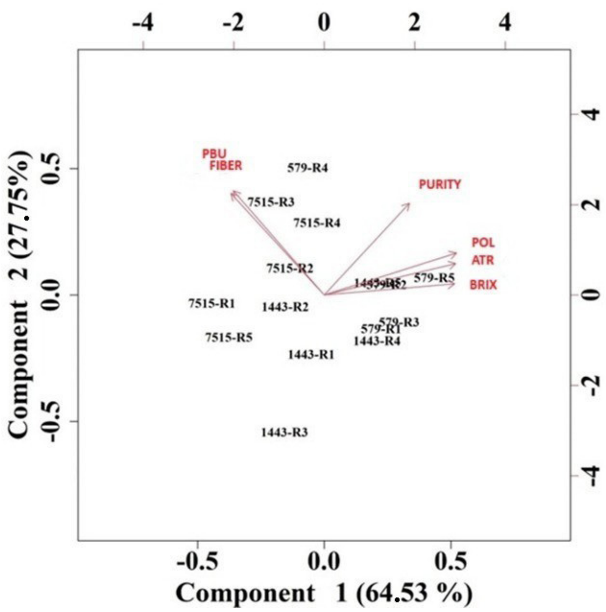

Figure 4 Principal component analysis between the variables BRIX, PBU, POL, PURITY, FIBER and ATR. RB 92-579; RB 04-1443; RB 86-7515.

The correlation matrices and Biplot showed positive and high correlations between the variables BRIX and POL, BRIX and ATR. The correlation between BRIX and PURITY showed a positive but moderate coefficient. However, the correlation coefficient is moderate and negative when correlating BRIX and PBU, BRIX and FIBRA. The correlation between PBU and FIBRA also showed a positive and high coefficient; however, when correlating PBU and PURITY, the coefficient, despite being positive, was low and negative, and moderate in the correlation between PBU and POL and PBU and ATR.

The correlation analysis between POL and PURITY and POL and ATR revealed high and positive coefficients, in contrast to the correlation between POL and FIBRA, with a negative and moderate coefficient. The correlation between the variable PURITY and ATR showed a positive and moderate coefficient, while the correlation coefficient between PURITY and FIBRA showed a positive but low coefficient. Finally, the correlation between FIBRA and ATR showed a negative and moderate coefficient (Table 2).

Regarding the arrangement of observations and vectors in the Biplot, the RB 92-579 variety presents significant BRIX, ATR, PURITY, and POL, while the opposite was observed for the RB 86-7515 variety (Fig. 4). The univariate bootstrap analyses demonstrate that there was a difference between all the variables evaluated. The RB 92-579 variety presented the highest BRIX, POL, PURITY, and ATR levels. While the RB 86-7515 variety expressed the lowest BRIX, POL, and ATR levels, it had the highest PBU and FIBER levels. Thus, the RB 04-1443 variety presented average values for all variables (Table 2).

Discussion

The results of this study confirmed the correlation between *D. impersonatella* attack and the variety and age of the sugarcane plant. It is believed that the pest's greater preference for the RB 92-579 and RB 04-1443 varieties may be related to the high sucrose content and low fiber content, characteristics found in both varieties cited by several authors (Cuenya and Mariotti, 1984; Oliveira et al., 2015), and reinforced by the data from the industrial analyses carried out in the present study. Sugarcane varieties with higher ATR and low fiber percentage are more susceptible to borer attack and pathogen activity.

Sucrose makes the plant more attractive to arthropod pests because it is a fundamental compound in developing such organisms, especially during the larval phase (Borges Filho et al., 2018). Meanwhile, the low fiber content results in a lower hardness of the bark (Singh et al., 2013), which facilitates the penetration of the borer into the stems. At the same time, this information justifies the lower incidence of borer in the RB 86-7515 variety, because, although it has a high sucrose content, it has a medium fiber content (ASSOCANA, 2020), which possibly makes the pest infestation difficult.

Another justification for the lower incidence of the borer in the RB 86-7515 variety is that this is an older variety when compared to the others in this study. Older plants tend to have greater natural resistance, since genetic improvement, to obtain more productive varieties with higher sugar concentration, often selects genotypes that are more susceptible to the pest (Dinardo-Miranda et al., 2013).

The increase in borer attack, related to plant aging, in the varieties RB 92-579 and RB 04-1443, is widely described in the literature. Srikanth and Kurup (2011), for example, highlight a higher incidence of borer in sugarcane when the plants are close to phenological maturity. This can be explained by the fact that older plants have mature internodes, providing the pest with food throughout its larval cycle. Furthermore, in more advanced stages, the plants have greater sucrose availability (Roberto et al., 2015).

However, it is essential to note that, despite the low incidence, *D. impersonatella* attacks were detected on 45-day-old plants. This scenario highlights the adaptability and opportunism of this pest when attacking less attractive plants. Plants up to four months old are vulnerable to damage caused by the borer, and, according to Mendonça et al. (1996), attacks at this age cause the death of the apical bud and, consequently, the death of the plant. Finally, information about the age of the plant and the behavior of varieties to *D. impersonatella* attacks is essential to guide the choice of the ideal time to control the pest, as well as the selection of the most appropriate genetic material for use in combination with other control tactics in Integrated Pest Management (IPM).

Conclusions

According to industrial analyses, the RB 92-579 variety presents significant levels of BRIX, ATR, PURITY, and POL, the RB 86-7515 variety presents lower levels of BRIX, POL, and ATR, but with higher levels of

PBU and FIBER, and the RB 04-1443 variety presents average values for these variables. The RB 92-579 variety is more susceptible to *D. impersonatella* attack than the others, regardless of age. In addition, the vulnerability to *D. impersonatella* attack in the RB 92-579 and RB 04-1443 varieties increases with the phenological advancement of the plant. These findings provide direct evidence of the sugarcane varieties most susceptible to *D. impersonatella* attack, offering a valuable tool for field monitoring and pest management. Detecting and mapping the presence of the pest within fields can improve control efficiency and guide the replacement of highly susceptible varieties with more resistant ones. Integrating these results into Integrated Pest Management (IPM) strategies can reduce pesticide use, improve juice quality, and promote sustainable practices, leading to direct economic benefits through higher yield per hectare and lower production costs.

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Conflicts of interest

The authors declare no conflicts of interest.

Author contribution statement

RBS, SLSJ, ASS, ASS, JBM, JLB, RO contributed equally to all stages of the preparation of this manuscript.

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